PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

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in its capacity as elected Office

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International application No.: PCT/IL98/00393	Applicant's or agent's file reference: 085/00623
International filing date: 18 August 1998 (18.08.98)	Priority date:

Applicant:
KAMINSKY, Ronald, F. et al

1. The designated Office is hereby notified of its election made:

   [X] in the demand filed with the International preliminary Examining Authority on:

   06 July 1999 (06.07.99)

   [ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

   [ ] was not

   made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

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(54) Title: INSPECTION OF PRINTED CIRCUIT BOARDS USING COLOR

(57) Abstract

A method of analysis of a printed circuit board comprising: generating an image of the printed circuit board, preferably a multicolor image; and determining the presence of an oxide from an analysis of the image, preferably from brightness values of pixels in the image.

INSPECTION OF PRINTED CIRCUIT BOARDS USING COLOR

FIELD OF THE INVENTION

The present invention is related to the field of inspection of patterned surfaces, such as printed circuit boards and in particular to the identification of certain types of conditions, such as conductor oxidation, using color.

BACKGROUND OF THE INVENTION

One widely used method for inspection of "bare" printed circuit boards having metalized portions and, unmetalized, laminate portions is to:

(a) illuminate the board with light which appears to come from a wide range of angular directions;

(b) image the illuminated portion;

(c) define the metalized portions from the image of the board; and

(d) determine defects in metalization on the board by one or more of comparison of the image with a standard image and analysis of the image with a set of standards or rules to determine if it meets the rules.

Among prior art publications which describe such methods are US Patents 4,758,888; 5,619,429; 5,774,572; and 5,774,573, the disclosures of which are incorporated herein by reference.

One of the problems in making this comparison is the determination of edges between areas covered by conductors on the board and areas without conductors. A number of publications, including, for example, US Patent 5,524,152, the disclosure of which is incorporated herein by reference, have suggested the use of color to improve this determination. In general, these methods image the board utilizing a color at which the contrast between the conductors and areas from which the conductors have been removed is maximized. This may be achieved by illuminating the surface with light which maximizes contrast or by filtering the light which is reflected prior to forming the image. In particular, the above referenced US Patent 5,524,152 generates one or more different images each based on a different filter to emphasize different materials, such as gold copper, etc.

US Patent 5,483,603, the disclosure of which is incorporated by reference, defines a region in RGB space that characterizes a conductor and a region in RGB space that characterizes a laminate. Pixels are classified as conductors or laminate depending on which regions contains their RGB values.

While ideally, the board should consist of only two types of areas, namely metal and bare substrate, unfortunately the metalization on a board is sometimes oxidized. Furthermore, several types of oxidation and various levels of severity of oxidation exist, making it difficult to determine criteria for reliably identifying oxidation.

5   Since oxidation is a widespread phenomena in printed circuit board manufacture, especially when the boards have been in storage for a considerable period of time and/or have been stored under less than ideal conditions, it would be useful to be able to reliably determine areas of oxidation on printed circuit boards. Such identification could be useful, for example, in avoiding classification of such areas as containing defects.

10   SUMMARY OF THE INVENTION

In a broad aspect of the invention, the present invention determines the presence of oxide on a conductor on a printed circuit board from an image of the printed circuit board.

In accordance with some preferred embodiments of the invention, color characteristics of light reflected from the surface of a printed circuit board are used to determine if the area is

15   an oxidized conductor. The method of the present invention may be used in any imaging system in which images at multiple colors are acquired.

According to one broad aspect of the present invention, the presence of an oxide (or another definable aspect of the pixel) is determined by comparing the color characteristics of a suspect pixel with the color characteristics of either the metalization or laminate portions,

20   preferably, the metal portions.

According to a second broad aspect of the present invention, the presence of an oxide (or another definable aspect of the image) is determined by comparing the color components of a suspect pixel utilizing a normalizing scale based on the color characteristics of either the metalization or laminate portions, preferably, the metal portions.

25   According to a third broad aspect of the present invention, the presence of an oxide is determined by first finding a region of the color space which is characteristic of oxide and then determining if the color values of a pixel is within this region.

In accordance with one aspect of some preferred embodiments of the invention, the determination of an oxide is made without directly excluding the presence of a laminate. In

30   addition, in some preferred embodiments of the invention, only "interior" pixels (that is pixels not near an edge) are classified as oxide.

In a preferred embodiment of the invention each of the color scales for RGB is first normalized between a low light level and the reflection from fine (unoxidized) copper.

Preferably, the "dark level" is set at a few gray levels above zero and the "copper level" is set at a few gray levels below the maximum gray level. For example, the darkest portion of the image may be set at 10 gray levels and the copper (brightest) gray level set at 230 gray levels for 8 bit quantification of light level.

5   In a preferred embodiment of the invention, a pixel having a red intensity below a red threshold level is determined not to be an oxide. For other pixels, for which not all of the colors have intensities within a range indicative of copper, preferably the red level is compared to the level of other colors. If the red (normalized) level is greater than both the green (normalized) and blue (normalized) levels, the pixel is identified as brown oxide, the most

10   prevalent type. Different combinations of characteristics may be used for determining the presence of other oxide types.

       In other preferred embodiments of the invention, a comparison is made with brightness levels of the laminate.

       Similar comparisons are useful for determining other types of oxidation and/or

15   laminate problems and may be useful for the determination of the presence of other materials such as gold, tin-lead, or double treated copper conductors, cyanide ester, polymid or teflon laminate, photoresist residues or dust.

       There is thus provided, in accordance with a preferred embodiment of the invention, a method of analysis of a printed circuit board comprising:

20   generating an image of the printed circuit board; and
           determining the presence of an oxide from an analysis of the image.

       Preferably, determination of the presence of an oxide is made without determining whether the pixel is a laminate pixel.

       Preferably, generating an image comprises generating a pixelated image having

25   brightness values for each pixel and determining the presence of the of an oxide comprises determining the presence of the oxide responsive to the brightness values.

       Preferably, generating an image comprises generating a plurality of images each at a different color and having brightness values for each pixel in each image and determining the presence of an oxide includes making the determination based on an analysis of the pixel

30   values in at least two of the images. Preferably, the plurality of images comprises a red, a green and a blue image.

       Preferably, determination of the presence of an oxide includes eliminating pixels from consideration based on a brightness value for a single color. Preferably the color is red and

pixels having a red brightness level below a given value are eliminated from consideration as being an oxide. Preferably, the color is red and wherein pixels having a red value above a given value are eliminated from consideration as being an oxide.

In a preferred embodiment of the invention, determination of the presence of an oxide includes eliminating pixels from consideration based on a comparison between the brightness level of two colors. Preferably, the two colors are red and green and wherein the pixel is eliminated if its red brightness value compared to that of copper is less than its green brightness value compared to copper. Preferably, the two colors are red and blue and wherein the pixel is eliminated if its red brightness value compared to that of copper is less than its blue brightness value compared to copper.

In a preferred embodiment of the invention, determination of the presence of an oxide includes eliminating pixels from consideration based on an analysis of the brightness levels of three colors.

In a preferred embodiment of the invention, determination of the presence of an oxide includes eliminating pixels from consideration based on a comparison between the brightness level of three colors with brightness levels for copper. Preferably, a pixel is eliminated from consideration as an oxide when its color brightness values have a Mahalanobis distance greater than a given value from the mean values of the brightness values for copper. Preferably, the given value for the Mahalanobis distance is between 4 and 8, more preferably, about 6.

In a preferred embodiment of the invention, the determination of the presence of an oxide is made based on a relationship between the brightness values of the image and brightness values characteristic of copper.

Preferably, the method includes:

determining a color gamut characteristic of the oxide; and

comparing the color values of a pixel to the determined gamut of values to determine if the pixel is an oxide.

There is further provided, in accordance with a preferred embodiment of the invention, a method of multi-color image processing, comprising:

generating a plurality of images of an object, said images being acquired at different wavelength ranges;

determining gradient values in the image; and

analyzing the multi-color images to determine characteristics of the object,

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wherein regions of the image at or near high gradients are analyzed differently from other regions of the image.

In preferred embodiments of the invention, the regions of high gradient are transition regions, such as edge regions and in particular edges between conductors and laminate.

In preferred embodiments of the invention, the regions of high gradient are excluded from analysis.

In preferred embodiments of the invention, the object is a printed circuit board.

The invention will be more clearly understood from the following description of non-limiting preferred embodiments thereof.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

In a preferred embodiment of the invention, a printed circuit board (PCB) is illuminated by multi-wavelength light and imaged in a plurality of colors, for example in RGB. While the methods of the invention are applicable to any imaging system in which images at multiple colors are acquired, in an especially preferred embodiment of the invention, the PCB is illuminated by and the images are acquired by the apparatus described in PCT patent application PCT/IL98/00285, filed June 15, 1998, the disclosure of which is incorporated by reference.

In a preferred embodiment of the invention in which it is desired to determine the presence of brown oxide, three color images, namely R, G and B images are generated. Optionally, as disclosed in PCT/IL98/00285, filters are used to reduce any cross-over of colors between the images, such that each image represents reflections in a different wavelength. Alternatively, white light is used for illumination and standard light division (and associated overlapping sensitivity) is used.

As a first preferred step in the determination, a set-up is performed to calibrate the system. This calibration is preferably performed utilizing a standard manufactured, bare, PCB, preferably fee of oxide. Preferably, an operator chooses a portion of the board which has a mix of interior copper pixels, edge pixels and some laminate pixels.

First, the brightness of the illumination and the camera and A/D parameters are adjusted such that the gray level for each of the colors RGB for subsequently acquired images will have a dark level of about 10 and a value for a copper pixel of about 230 for 8 bit quantification of light level.

The next step is to define a "low sure" threshold from an analysis of transition pixels (pixels on or near transitions between conductor and laminate). This calculation is in

accordance with the calculation detailed in Fig. 15 from US Patent 5,774,573 (Caspi et al.) except that only the gray level value is accumulated, not ordered pairs of (gray level, gray level difference). The object of this threshold is to define pixels whose red level is so low that they cannot be an oxide. Other thresholds and methods of defining such thresholds may be used

5   instead of the "low-sure" threshold.

The next step in the set-up is to produce a 3-D histogram of the colors of all the interior copper pixels in the region of limited size. It has been found that a region of 700 by 700 pixels gives adequate statistics. For the 3-D histogram, the mean is computed. The mean may also be computed from the three separate color distributions.

10   Preferably, a covariance matrix is formed from the values. This matrix is:

$$\begin{matrix} \sum \frac{(R_i - \overline{R})^2}{(N-1)} & \sum \frac{(R_i - \overline{R}) \bullet (G_i - \overline{G})}{(N-1)} & \sum \frac{(R_i - \overline{R}) \bullet (B_i - \overline{B})}{(N-1)} \\ \sum \frac{(R_i - \overline{R}) \bullet (G_i - \overline{G})}{(N-1)} & \sum \frac{(G_i - \overline{G})^2}{(N-1)} & \sum \frac{(G_i - \overline{G}) \bullet (B_i - \overline{B})}{(N-1)} \\ \sum \frac{(R_i - \overline{R}) \bullet (B_i - \overline{B})}{(N-1)} & \sum \frac{(G_i - \overline{G}) \bullet (B_i - \overline{B})}{(N-1)} & \sum \frac{(B_i - \overline{B})^2}{(N-1)} \end{matrix}$$

This matrix is inverted to form an inverted covariance matrix. This inverted matrix is used to determine if a pixel is an oxide.

In a preferred embodiment of the invention, the following rules are applied to image

15   pixels in a PC board under test to determine if a pixel is oxidized.

1) if the pixel is at a strong gradient (for example, it is an edge pixel), it is not checked and is not marked as an oxide;

2) if is Mahalanobis distance (as defined below) from the mean value of copper pixels is less than some given value, it is not an oxide; This value may vary between about 4 and 8,

20   with 6 being a preferred value;

3) if the red pixel value is less than the low-sure threshold for red, it is not classified as an oxide (it is definitely laminate);

4) optionally, if red is less than green for a pixel, it is not classified as an oxide;

5) optionally, if red is less than blue for a pixel, it is not classified as an oxide; and

25   6) optionally, if the red value is greater than some high value (for example, 220) it is not classified as an oxide.

The Mahalanobis distance for a pixel is determined by forming a vector and pre-multiplying the inverted covariance matrix by the vector and then post-multiplying the product

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by the transpose of the vector. The scalar that results from this "modified inner product" of the vector is the square of the Mahalanobis distance .

A preferred algorithm for determining if a pixel is at a strong gradient (i.e., it is considered to be an edge pixel and thus not subject to the above analysis) is:

5   Let I[x,y] be the gray level value of the red image at location (x,y).

To calculate if the pixel at location (x,y) is an edge pixel:

$$
\begin{aligned}
\text{Let } s = {} & \text{ceo}(I[x-2,y],I[x-1,y],I[x,y],I[x+1,y],I[x+2,y]) \\
& + \text{ceo}(I[x,y-2],I[x,y-1],I[x,y],I[x,y+1],I[x,y+2]) \\
& + \text{ced}(I[x-2,y-2],I[x-1,y-1],I[x,y],I[x+1,y+1],I[x+2,y+2]) \\
& + \text{ced}(I[x-2,y+2],I[x-1,y+1],I[x,y],I[x+1,y-1],I[x+2,y-2])
\end{aligned}
$$

where the functions ceo() and ced() are defined by the computer program
15   fragment below.

Then if s >= 12, the pixel at (x,y) is an edge pixel.

```
> typedef unsigned char uchar;
>
> static int sst[4][4] = { {1, 2, 2, 2}, {2,-1, 2, 2},
>                          {2, 2, 0, 0}, {2, 2, 0, 0}};
>
> int f(int d)
> {
>   return (abs(d) < 4 ? 0 : (abs(d) < 8 ? 1 :
>   (abs(d) < 12 ? 2 : (abs(d) < 16 ? 3 :
>   (abs(d) < 24 ? 4 : (abs(d) < 36 ? 5 :
>   (abs(d) < 128 ? 6 : 7))))))) * (d < 0 ? -1 : 1);
> }
>
> void ht(float d1, float d2, int *s, float *v)
> {
>   *v = 0.375*d1 + 0.125*d2 ;
>
>   if ( fabs(*v) < 0.3 )
>      *s = (fabs(d1) < 0.1) ? 2 : 3 ;
>   else {
>      *s = (*v>0) ? 0 : 1 ;
>   }
>   *v = fabs(*v);
> }
>
> int ct(int d[4])
> {
>   int s, s1, s2;
>   float v1, v2, ret;
>   int t, v;
```

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```
>
>   ht(-d[1], -d[0], &s1, &v1);
>   ht(d[2], d[3], &s2, &v2);
>
>   ret = (v1+v2+1)/2 ;
>   if (ret > 3)
>       ret = 3;
>   if (ret < -3)
>       ret = -3;
>   v = (int) ret ;
>
>   s = sst[s1][s2];
>
>   if (s == 2) {
>       if (fabs(v1) > 2 || fabs(v2) > 2)
>           t = 4;
>       else
>           t = 0;
>   }
>   else
>       t = 0;
>
>   return t;
> }
>
> int ceo(uchar g0, uchar g1, uchar g2, uchar g3, uchar g4)
> {
>   int d[4];
>
>   d[0] = f(g1-g0);
>   d[1] = f(g2-g1);
>   d[2] = f(g3-g2);
>   d[3] = f(g4-g3);
>   return ct(d);
> }
>
> int ced(uchar g0, uchar g1, uchar g2, uchar g3, uchar g4)
> {
>   int d[4];
>
>   d[0] = f((g1-g0)/sqrt(2));
>   d[1] = f((g2-g1)/sqrt(2));
>   d[2] = f((g3-g2)/sqrt(2));
>   d[3] = f((g4-g3)/sqrt(2));
>   return ct(d);
> }
```

In an alternate preferred embodiment of the invention, a multi-dimensional region of color space characteristic of an oxide, whose presence is to be tested, is determined. Such a determination may be made by imaging a number of samples of oxide and determining the

range, in color space, of the images. During testing, the color values of teat pixels are compared to the values in the determined region. If the values are within the region, the pixel is labeled as an oxide. Optionally, edge and other high gradient pixels are excluded from classification as oxides. While such color maps have been used, in the past, to determine metal

5   and laminate, they have not been used to determine the presence of oxide and have not been used in conjunction with gradient information. Furthermore, this method is easily adapted to testing for other types of oxide and even to the presence of dust on conductors.

One preferred use of the information determined by the above described method is in avoiding the classification oxide or dust pixels as faults in a printed circuit board. Since these

10   pixels generally have a brightness between that of copper and laminate, they may sometimes be classified as laminate by normal threshold programs. Edge finding programs may also have difficulty in determining edges near oxide. Thus, when the above method determines that a pixel is oxide, it is, for the purposes of a fault determination program, defined as a metal pixel.

The present invention has been described in conjunction with preferred, non-limiting,

15   embodiments thereof. It should be understood that variations on these embodiments, within the scope of the invention, as defined by the following claims, will occur to persons of skill in the art. In the following claims, where the words "comprising," comprises," including" or "includes" are used these words mean that the apparatus or method includes the following structure or steps, but may (but need not) include other structure or steps.

CLAIMS

1.   A method of analysis of a printed circuit board comprising:

generating an image of the printed circuit board; and

determining the presence of an oxide from an analysis of the image.

2.   A method according to claim 1 wherein determination of the presence of an oxide is made without determining whether the pixel is a laminate pixel.

3.   A method according to claim 1 or claim 2 wherein generating an image comprises generating a pixelated image having brightness values for each pixel and wherein determining the presence of the of an oxide comprises determining the presence of the oxide responsive to the brightness values.

4.   A method according to claim 1 or claim 2 wherein generating an image comprises generating a plurality of images each at a different color and having brightness values for each pixel in each image and wherein determining the presence of an oxide includes making the determination based on an analysis of the pixel values in at least two of the images.

5.   A method according to claim 4 wherein the plurality of images comprises a red, a green and a blue image.

6.   A method according to claim 4 or claim 5 wherein determination of the presence of an oxide includes eliminating pixels from consideration based on a brightness value for a single color.

7.   A method according to claim 6 wherein the color is red and wherein pixels having a red brightness level below a given value are eliminated from consideration as being an oxide.

8.   A method according to claim 6 or claim 7 wherein the color is red and wherein pixels having a red value above a given value are eliminated from consideration as being an oxide.

9.   A method according to any of claims 6-8 wherein determination of the presence of an oxide includes eliminating pixels from consideration based on a comparison between the brightness level of two colors.

5   10.   A method according to claim 9 wherein the two colors are red and green and wherein the pixel is eliminated if its red brightness value compared to that of copper is less than its green brightness value compared to copper.

11.   A method according to claim 9 or claim 10 wherein the two colors are red and blue and 10   wherein the pixel is eliminated if its red brightness value compared to that of copper is less than its blue brightness value compared to copper.

12.   A method according to any of claims 6-11 wherein determination of the presence of an oxide includes eliminating pixels from consideration based on an analysis of the brightness 15   levels of three colors.

13.   A method according to any of claims 6-12 wherein determination of the presence of an oxide includes eliminating pixels from consideration based on a comparison between the brightness level of three colors with brightness levels for copper.
20

14.   A method according to claim 13 wherein a pixel is eliminated from consideration as an oxide when its color brightness values have a Mahalanobis distance greater than a given value from the mean values of the brightness values for copper.

25   15.   A method according to claim 14 wherein the given value for the Mahalanobis distance is between 4 and 8.

16.   A method according to claim 14 wherein the given value for the Mahalanobis distance is about 6.
30

17.   A method according to any of claims 2-16 wherein the determination of the presence of an oxide is made based on a relationship between the brightness values of the image and brightness values characteristic of copper.

18.   A method according to any of claim 4, 5 or 12 and comprising:

        determining a color gamut characteristic of the oxide; and

        comparing the color values of a pixel to the determined gamut of values to determine if

5   the pixel is an oxide.

19.   A method of multi-color image processing, comprising:

        generating a plurality of images of an object, said images being acquired at different

wavelength ranges;

10   determining gradient values in the image; and

        analyzing the multi-color images to determine characteristics of the object,

        wherein regions of the image at or near high gradients are analyzed differently from

other regions of the image.

15   20.   A method according to claim 19 wherein the regions of high gradient are transition

regions.

21.   A method according to claim 19 or claim 20 wherein the regions of high gradient are

edge regions.

20

22.   A method according to any of claims 19-21 wherein the regions of high gradient are

excluded from analysis.

23.   A method according to any of claims 19-22 wherein the regions of high gradient

25   include edges between conductors and laminate.

24.   A method according to any of claims 19-23 wherein the object is a printed circuit

board.

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INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   G01N21/88   G01R31/309   G06T7/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6   G01N   G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 594 146 A (ADVANCED INTERCONNECTION TECH) 27 April 1994 see page 1, line 39 – line 42 see page 4, line 9 – line 47; figure 1	1
A	EP 0 160 781 A (IBM) 13 November 1985 see page 6, line 30 – page 7, line 29 see page 10, line 7 – page 11, line 7 see page 11, line 25 – page 12, line 25; figures 2,9	1
A	EP 0 426 182 A (KLA INSTR CORP) 8 May 1991 see column 1, line 1-3 see column 7, line 52 – column 8, line 41 see column 28, line 6 – line 39; claim 1; figure 1	1

☐ Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

Date of the actual completion of the international search	Date of mailing of the international search report
12 April 1999	21/04/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Tabellion, M

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
EP 0594146	A	27-04-1994	CA	2108915 A	23-04-1994
			JP	2824552 B	11-11-1998
			JP	7077496 A	20-03-1995
			US	5483603 A	09-01-1996
EP 0160781	A	13-11-1985	US	4650333 A	17-03-1987
			JP	1980056 C	17-10-1995
			JP	6103165 B	14-12-1994
			JP	60219504 A	02-11-1985
EP 0426182	A	08-05-1991	US	5085517 A	04-02-1992
			DE	69029561 D	13-02-1997
			DE	69029561 T	28-05-1997
			JP	3167456 A	19-07-1991

●ATENT COOPERATION TREAT●

From the INTERNATIONAL SEARCHING AUTHORITY

To:
FENSTER & Company
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P.O. BOX 2741
49127 Petach Tikva
ISRAEL

[Stamp: Fenster & Co. 28 -04- 1999 Docketed by: RECEIVED 28 -04- 1999 FENSTER & Co.]

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NOTIFICATION OF TRANSMITTAL OF
THE INTERNATIONAL SEARCH REPORT
OR THE DECLARATION

(PCT Rule 44.1)

Date of mailing *(day/month/year)*	21/04/1999

Applicant's or agent's file reference	
085/00623	**FOR FURTHER ACTION** See paragraphs 1 and 4 below

International application No.	International filing date *(day/month/year)*
PCT/IL 98/ 00393	18/08/1998

Applicant
ORBOTECH LTD. et al.

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1. [X] The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

   When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

   Where? Directly to the   International Bureau of WIPO
                                   34, chemin des Colombettes
                                   1211 Geneva 20, Switzerland
                                   Fascimile No.: (41-22) 740.14.35

   For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   [ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

   [ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):**   The applicant is reminded of the following:

   Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

   Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

   Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Johannes Hijzelendoorn

Form PCT/ISA/220 (July 1998)

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international pbulication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the International application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When?
Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How?
Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped),whether

(i)   the claim is unchanged;

(ii)   the claim is cancelled;

(iii) the claim is new;

(iv) the claim replaces one or more claims as filed;

(v)   the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."

2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."

3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."

4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international appplication is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for International preliminary examination has already been filed

If, at the time of filing any amendments under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the same time of filing the amendments with the International Bureau, also file a copy of such amendments with the International Preliminary Examining Authority (see Rule 62.2(a), first sentence).

Consequence with regard to translation of the International application for entry into the national phase

The applicant's attention is drawn to the fact that, where upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 085/00623	**FOR FURTHER ACTION**	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
International application No. PCT/IL 98/ 00393	International filing date *(day/month/year)* 18/08/1998	(Earliest) Priority Date *(day/month/year)*
Applicant ORBOTECH LTD. et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of ____2____ sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

    a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

    [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

    b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

    [ ] contained in the international application in written form.

    [ ] filed together with the international application in computer readable form.

    [ ] furnished subsequently to this Authority in written form.

    [ ] furnished subsequently to this Authority in computer readble form.

    [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

    [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

    [X] the text is approved as submitted by the applicant.

    [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

    [X] the text is approved as submitted by the applicant.

    [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No.

    [ ] as suggested by the applicant.   [X] None of the figures.

    [ ] because the applicant failed to suggest a figure.

    [ ] because this figure better characterizes the invention.

Form PCT/ISA/210 (first sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   G01N21/88   G01R31/309   G06T7/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6   G01N   G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 594 146 A (ADVANCED INTERCONNECTION TECH) 27 April 1994 see page 1, line 39 – line 42 see page 4, line 9 – line 47; figure 1	1
A	EP 0 160 781 A (IBM) 13 November 1985 see page 6, line 30 – page 7, line 29 see page 10, line 7 – page 11, line 7 see page 11, line 25 – page 12, line 25; figures 2,9	1
A	EP 0 426 182 A (KLA INSTR CORP) 8 May 1991 see column 1, line 1-3 see column 7, line 52 – column 8, line 41 see column 28, line 6 – line 39; claim 1; figure 1	1

[ ] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

12 April 1999

Date of mailing of the international search report

21/04/1999

Name and mailing address of the ISA
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Tabellion, M

Form PCT/ISA/210 (second sheet) (July 1992)

1

| Patent document cited in search report		Publication date	Patent family member(s)		Publication date
EP 0594146	A	27-04-1994	CA	2108915 A	23-04-1994
			JP	2824552 B	11-11-1998
			JP	7077496 A	20-03-1995
			US	5483603 A	09-01-1996
EP 0160781	A	13-11-1985	US	4650333 A	17-03-1987
			JP	1980056 C	17-10-1995
			JP	6103165 B	14-12-1994
			JP	60219504 A	02-11-1985
EP 0426182	A	08-05-1991	US	5085517 A	04-02-1992
			DE	69029561 D	13-02-1997
			DE	69029561 T	28-05-1997
			JP	3167456 A	19-07-1991

● **PATENT COOPERATION TREATY**

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

WEISS, P.
FENSTER & COMPANY PATENT
ATTORNEYS, LTD
P.O.Box 10256
Petach Tikva 49002
ISRAEL

RECEIVED
- 3 -05- 2000
FENSTER & Co.

PCT
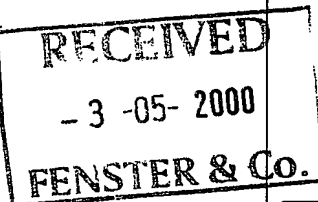
NOTIFICATION OF TRANSMITTAL OF
THE INTERNATIONAL PRELIMINARY
EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing (day/month/year)	2 8. 04. 00

Applicant's or agent's file reference 085/00623	**IMPORTANT NOTIFICATION**

International application No. PCT/IL98/00393	International filing date (day/month/year) 18/08/1998	Priority date (day/month/year) 18/08/1998

Applicant
ORBOTECH LTD. et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

   The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

   Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

   For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Weber, R Tel.+49 89 2399-2382

Form PCT/IPEA/416 (July 1992)

PATENT COOPERATION TREATY

PCT

REC'D 0 1 MAY 2000

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 085/00623	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/IL98/00393	International filing date *(day/month/year)* 18/08/1998	Priority date *(day/month/year)* 18/08/1998

International Patent Classification (IPC) or national classification and IPC
G01N21/88

Applicant
ORBOTECH LTD. et al.

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 8 sheets, including this cover sheet.

    ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

    These annexes consist of a total of 3 sheets.

3. This report contains indications relating to the following items:

    I   ☒   Basis of the report

    II   ☐   Priority

    III   ☒   Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

    IV   ☒   Lack of unity of invention

    V   ☒   Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement

    VI   ☐   Certain documents cited

    VII   ☒   Certain defects in the international application

    VIII   ☒   Certain observations on the international application

Date of submission of the demand 06/07/1999	Date of completion of this report 2 8. 04. 00
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Meyer, F Telephone No. +49 89 2399 2233

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY
EXAMINATION REPORT

I. Basis of the report

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

Description, pages:

1-9	as originally filed

Claims, No.:

1-22	as received on	10/02/2000	with letter of	08/02/2000

2. The amendments have resulted in the cancellation of:

☐ the description,   pages:

☒ the claims,   Nos.:   23,24

☐ the drawings,   sheets:

3. ☒ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   see separate sheet

4. Additional observations, if necessary:

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been examined in respect of:

☐ the entire international application.

☒ claims Nos. 19-22.

because:

☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (*specify*):

☒ the description, claims or drawings (*indicate particular elements below*) or said claims Nos. 19 are so unclear that no meaningful opinion could be formed (*specify*):

see separate sheet

☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

☐ no international search report has been established for the said claims Nos. .

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

   ☐ restricted the claims.

   ☐ paid additional fees.

   ☐ paid additional fees under protest.

   ☐ neither restricted nor paid additional fees.

2. ☒ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

   ☐ complied with.

   ☒ not complied with for the following reasons:

   see separate sheet

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

   ☒ all parts.

   ☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-18
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-18
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-18
	No:	Claims	

2. Citations and explanations

   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

   see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

   see separate sheet

1.   Reference is made to the following document:

   D1: EP-A-0 594 146
   D2: EP-A-0 160 781
   D3: EP-A-0 426 182

Re Item I.3

2.   The amendments filed with the letter dated 08.02.2000 introduce subject-matter
   which extends beyond the content of the application as filed, contrary to Article
   34(2)(b) PCT. The amendment concerned is the following:
   The applicant has added the feature "determining gradient values of the intensity
   in an image" in **claim 19**, but no basis for this amendment can be found in the
   application as filed.
   Consequently, this report has been established as if the above stated amendment
   had not been made.

Re Item III

3.   The questions whether the claimed invention appears to be novel, to involve an
   inventive step or to be industrially applicable have not been examined in respect
   of **claims 19-22** because independent **claim 19** is so unclear (see paragraph 7.
   below) that no meaningful opinion could be formed.

Re Item IV

4.   The application lacks unity within the meaning of Rule 13.1 PCT for the following
   reasons:

4.1.   The common concept linking together the independent **claims 1 and 19** is the
   following:
   - A method of analysis of an object, comprising the steps of

    - generating an image of the object,

    - determining characteristics of the object from an analysis of the image.

4.2. This common concept is not novel, see document D1 (p.2 l.39-41, p.3 l.20).
The following further features are also known from D1:

    - the object to be analysed is a printed circuit board (abstract l.1),

    - the method of analysis is a multi-color image processing method (p.3 l.21-22),

    - generating a plurality of images of the object, said images being acquired at
different wavelength ranges (p.3 l.20-22);

4.3. Hence it is considered that the following separate inventions are not so linked as
to form a single general inventive concept:

    (i)   A method of analysis of a printed circuit board wherein the characteristic to
be determined is the presence of an oxide (**claim 1**).

    (ii)   A method of multi-color image processing wherein gradient values are
determined in the image(s) and wherein regions of the image(s) at or near high
gradients are analysed differently from other regions of the image(s) (**claim 19**).

Re Item V

5.1. **Novelty - independent claim 1:**

    D1, which is considered to represent the closest prior art, discloses a method for
optical inspection of printed circuit boards. A pixeled RGB image is generated
from a board. Regions in RGB space are defined that characterize a conductor or
a laminate. Pixels are classified as conductors or laminate depending on which
region contains their RGB values. The presence of an oxide is <u>not</u> determined
from an analysis of the color image.

    D2 discloses a method for detecting printed circuit wiring defects and for
measuring circuit feature height relative to the substrate. The surface of the
printed circuit board is scanned with a light slit and the reflected intensity signal is
detected and analyzed. No image of the printed circuit board is generated and the
presence of an oxide is not determined.

    D3 discloses a method for inspecting surface features of a substrate, e.g. a
printed circuit board. The surface of the board is scanned with a light beam. With

special illumination of the surface, dark CuO can be distinguished from brighter substrate. No image of the printed circuit board is generated.

The subject-matter of **claim 1** thus satisfies the requirements of Article 33(2) PCT.

5.2. **Inventive step - independent claim 1:**

Starting from D1, the **problem to be solved** by the present invention is to provide an improved method of analysis of a printed circuit board with which the conductors and the laminate can more reliably be distinguished.

Solution provided by the invention is to generate an image of the printed circuit board and to determine the presence of an oxide from an analysis of the image. The reflectivity of an oxidized conductor is lower than that of a clean conductor and as such closer to the reflectivity of the substrate. Identification of oxidized conductors can hence be used to avoid classification of such areas as containing defects.

Also the lower reflectivity of oxide is mentioned in D1 to be problematic, no solution is given, in particular, no hint is given as to determine the presence of oxide. D2 does also not disclose or hint at this solution. D3 discloses a different solution (see paragraph 5.1. above) to the above stated problem, as such leading away from the solution given in the present application.

The subject-matter of **claim 1** thus satisfies the requirements of Article 33(3) PCT.

5.3. **Claims 2-18** are dependent on claim 1 and therefore also satisfy the requirements of Article 33(1) PCT.

Re Item VII

6.1. Independent **claims 1 and 19** are not drafted in the two-part form in accordance with Rule 6.3(b) PCT, which in the present case would have been appropriate, with those features known in combination from the prior art (document D1, see paragraphs 4.1.-4.3. above) being placed in a preamble (Rule 6.3(b)(i) PCT) and with the remaining features being included in a characterising part (Rule 6.3(b)(ii) PCT).

6.2. In the description (p.1 l.17-18,21-22,29; p.5 l.16-17), the applicant incorporates by

reference the disclosure of a number of US patents and of a PCT application. If the applicant had the opinion, that the said disclosure contained matter which was essential for carrying out the invention as meant by Article 5 PCT, the applicant should have expressly incorporated this matter into the description. Otherwise, these passages should have been deleted from the description (see the PCT Guidelines PCT/GL/3 II 4.17).

6.3.   On p.3 l.18-21, the wording of <u>independent</u> **claim 1** is reflected but it is stated that the described method is a <u>preferred embodiment</u> of the invention. This inconsistency should have been removed.
The same applies to p.4 l.27 - p.5 l.2 with respect to independent **claim 19**.

6.4.   The paragraph on p.9 l.14-19 is superfluous and should hence have been deleted.

Re Item VIII

7.   The application does not meet the requirements of Article 6 PCT, because some of the claims are not clear.

7.1.   The feature "determining gradient values in the image" in **claim 19** is unclear. It is not clear with regard to <u>what</u> (intensity, RGB values, ...) to determine gradient values (see paragraph 2. above).

7.2.   The feature "wherein regions of the image at or near high gradients are <u>analyzed differently</u> from other regions of the image" in **claim 19** is vague and indefinite. Concrete Method steps should have been added, specifying the analysis of the two different regions.

CLAIMS

1.   A method of analysis of a printed circuit board comprising:

generating an image of the printed circuit board; and

5   determining the presence of an oxide from an analysis of the image.

2.   A method according to claim 1 wherein determination of the presence of an oxide at a particular pixel of the image is made without determining whether the pixel is a laminate pixel.

10   3.   A method according to claim 1 or claim 2 wherein generating an image comprises generating a pixelated image having brightness values for each pixel and wherein determining the presence of the of an oxide comprises determining the presence of the oxide responsive to the brightness values.

15   4.   A method according to claim 1 or claim 2 wherein generating an image comprises generating a plurality of images each at a different color and having brightness values for each pixel in each image and wherein determining the presence of an oxide includes making the determination based on an analysis of the pixel values in at least two of the images.

20   5.   A method according to claim 4 wherein the plurality of images comprises a red, a green and a blue image.

6.   A method according to claim 4 or claim 5 wherein determination of the presence of an oxide includes eliminating pixels from consideration based on a brightness value for a single

25   color.

7.   A method according to claim 6 wherein the color is red and wherein pixels having a red brightness level below a lower given value are eliminated from consideration as being an oxide.

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8.   A method according to claim 6 or claim 7 wherein the color is red and wherein pixels having a red value above an upper given value are eliminated from consideration as being an oxide.

9.   A method according to any of claims 6-8 wherein determination of the presence of an oxide includes eliminating pixels from consideration based on a comparison between the brightness level of two colors.

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10.   A method according to claim 9 wherein the two colors are red and green and wherein the pixel is eliminated if its red brightness value compared to that of copper is less than its green brightness value compared to copper.

10   11.   A method according to claim 9 or claim 10 wherein the two colors are red and blue and wherein the pixel is eliminated if its red brightness value compared to that of copper is less than its blue brightness value compared to copper.

12.   A method according to any of claims 6-11 wherein determination of the presence of an
15   oxide includes eliminating pixels from consideration based on an analysis of the brightness levels of three colors.

13.   A method according to any of claims 6-12 wherein determination of the presence of an oxide includes eliminating pixels from consideration based on a comparison between the
20   brightness level of three colors with brightness levels for copper.

14.   A method according to claim 13 wherein a pixel is eliminated from consideration as an oxide when its color brightness values have a Mahalanobis distance greater than a given value from the mean values of the brightness values for copper.

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15.   A method according to claim 14 wherein the given value for the Mahalanobis distance is between 4 and 8.

16.   A method according to claim 14 wherein the given value for the Mahalanobis distance
30   is about 6.

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AMENDED SHEET

17.   A method according to any of claims 2-16 wherein the determination of the presence of an oxide is made based on a relationship between the brightness values of the image and brightness values characteristic of copper.

5   18.   A method according to any of claim 4, 5 or 12 and comprising:

determining a color gamut characteristic of the oxide; and

comparing the color values of a pixel to the determined gamut of values to determine if the pixel is an oxide.

10   19.   A method of multi-color image processing, comprising:

generating a plurality of images of an object, said images being acquired at different wavelength ranges;

determining gradient values of the intensity in an image; and

analyzing the multi-color images to determine characteristics of the object,

15   wherein regions of the image at or near high gradients are analyzed differently from other regions of the image.

20.   A method according to claim 19 wherein the regions at high gradients are excluded from analysis.

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21.   A method according to claim 19 or claim 20 wherein regions of relatively lower gradients are analyzed to determine characteristics of the object.

22.   A method according to any of claims 19-21 wherein the object is a printed circuit

25   board.